DOCUMENT RESUME

ED 229 262 SE 041 544

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TITLE Fourth International Congress on Mathematics Education. Indigenous Mathematics Project. Working Paper 5. [Four Papers Presented by Papua New Guinea Department of Education Personnel].
INSTITUTION Indigenous Mathematics Project, Port Moresby (Papua New Guinea).
SPONS AGENCY Papua New Guinea, Dept. of Education, Port Moresby.; United Nations Educational, Scientific, and Cultural Organization, Paris (France).
PUB DATE Aug 80
NOTE 49p.; Papers presented at the International Congress on Mathematics Education (4th, Berkeley, CA, August, 1980). For related documents, see SE 041 540-555.
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cross Cultural Studies; *Curriculum Development; *Educational Assessment; Educational Research; Elementary Secondary Education; Ethnography; Field Studies; Mathematics Achievement; Mathematics Curriculum; *Mathematics Education; *Mathematics Instruction
IDENTIFIERS *Indigenous Mathematics Project; Mathematics Education Research; *Papua New Guinea

ABSTRACT

The four papers in this report summarize several research and development efforts currently being undertaken on behalf of the Government of Papua New Guinea. In the first paper, the Indigenous Mathematics Project, established in 1977 to investigate various aspects of traditional and Western mathematical development, is described. The intent of the five-year program was to carry out basic crosscultural cognitive development research, as well as to document indigenous counting, classification, and measurement systems used in the region, which might have differential effects on children's learning in mathematics at school. Pilot instructional materials were developed to assess the feasibility of utilizing indigenous mathematics as a basis for future curriculum development. Details of the implementation, including materials, sites, and procedures, are reported. The second paper provides a brief overview of the project, while the third paper describes the secondary mathematics curriculum development project in detail. Finally, national assessment of mathematics achievement in Papua New Guinea is discussed. (MNS)

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INDIGENOUS MATHEMATICS PROJECT

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FOURTH INTERNATIONAL CONGRESS ON MATHEMATICS EDUCATION

Souviney, Kada, Malaga
Lancy
Britt
Roberts

Working Paper 5
August 1980

THE INDIGENOUS MATHEMATICS PROJECT

This series of working papers and research reports has been published to provide a comprehensive source of documentation on research and development efforts associated with the Indigenous Mathematics Project. The Project was established in 1977 by the Government of Papua New Guinea to investigate various aspects of traditional mathematics development. During the first phase (1977–79) of the five year program, basic research in crosscultural cognitive development was carried out and indigenous counting, classification and measurement systems used throughout the country were documented. During the second phase of the project (jointly funded by the Department of Education and UNESCO), pilot instructional materials were developed and trialled. The intent was to assess the feasibility of utilizing complementary aspects of indigenous and Western mathematics as a basis for developing culturally relevant student materials, instructional aids and teachers' guides which reflect the practical constraints of the community school environment. The results of IMP work are intended to inform future curriculum development in an effort to provide more appropriate instructional materials and learning aids for Community Schools throughout Papua New Guinea.

Series Editor: Randall Souviney
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INDIGENOUS MATHEMATICS PROJECT

WORKING PAPER SERIES

1. Learning to Compute.
   R. Souviney, January 1980.

2. Strategies for Mathematical Problem Solving.
   R. Souviney, March 1980.

3. Assessment Administration Guide.
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4. Field Guide for Documenting Classroom Events and Community Environment.
   P. Levin, M. Gearhart and R. Souviney, June 1980.

5. International Congress on Mathematics Education.
   R. Souviney, V. Kada and D. Malaga; D. Lancy; M. Britt; B. Roberts, August 1980.

6. Andra Community School Field Report.
   P. Levin, November 1980.

7. Oro.o Community School Field Report.
   J. Lineberger, November 1980.

8. Divanap Community School Field Report.
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The Indigenous Mathematics Project: An Overview ..... D.F. Lancy

Secondary Mathematics – a curriculum development project ..... M. Britt

National Assessment of Mathematics Achievement in Papua New Guinea ..... R.E. Roberts

The four papers included in this report were presented by Department of Education and UNESCO personnel at the Fourth International Congress on Mathematics Education held at the University of California, Berkeley, August 1980. The reports summerize several research and development efforts currently being undertaken on behalf of the Government of Papua New Guinea.

THE INDIGENOUS MATHEMATICS PROJECT

of

Papua New Guinea

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Paper presented at the Fourth International Congress on Mathematics Education, Berkeley, California, August, 1980. Excerpts from a field note guide developed by P. Levin, M. Gearhart and R. Souviney in collaboration with K. Johnson, J. Lineberger and B. Rowe have been included in this project status report. The author wishes to express his appreciation to the IMP Research Associates for their invaluable assistance throughout the development of the field portion of the reported study.

The Indigenous Mathematics Project was established in 1977 by the government of Papua New Guinea to investigate various aspects of traditional and Western mathematics development. The intent of the five year program was to carry out basic crosscultural cognitive development research, as well as document indigenous counting, classification and measurement systems used throughout the region. It was anticipated that the availability of various categories of indigenous systems would have differential effects on children's learning of mathematics at school. The second phase of the project is to develop pilot instructional materials to asess the feasibility of utilizing indigenous mathematics as a basis for developping student materials, instructional aids and teachers' guides which are culturally relevant and reflect the practical constraints of the community school environment. The results of IMP work will inform future curriculum development efforts in attempts to provide more appropriate instructional materials and learning aids for community schools throughout the country.

COMMUNITY SCHOOLS

Since independence, the emphasis in government policy has been to encourage education for village life at the primary level. This goal, as opposed to a narrow policy of academic preparation for higher education, was in response to problems associated with an increasing population of disinfranchised youth who were unable to win positions in a secondary school. The intent was to "dampen the perceived link between schooling and employment" manifested by a long colonial history and elitist model of schooling (Smith, et al, 1979).

Six aims for community-based education were reviewed in the Papua New Guinea *National Education Strategy* (IASER, 1979):

(a) The new nation demanded a basic education which prepared young people for their lives of tomorrow – in the rural areas of the country. This basic education, up to grade 6, was to be suitable for the child whose formal education would end at this stage.

(b) Basic education had to prepare properly those students who would go on to high school and perhaps to tertiary school.

(c) Basic education would encourage young people to find, and to make, employment opportunities in their own communities, whether rural or urban, as alternatives to secondary education and to more orthodox wage employment.

(d) The new philosophy, which is now being introduced, assumed a basic education which was community-based, i.e. where each school was particularly appropriate to its own setting, with the syllabus interpreted and handled with the community clearly in mind. Community members would be actively involved in the life of the school, including development projects.

(e) Learning experiences had to be related closely to what was familiar in the pupils' own lives and community. The integration, relevance and involvement of the school in the village, and the village in the school, would help to hold the school-leaver to the community; so it was argued.

(f) A successful community school would be one that was seen as a community development project itself; therefore it would receive active support from parents and the community at large.

The number of community schools has increased dramatically over the past 10 years. There are currently over 350,000 children being serviced by approximately 2000 community schools and 8000 teachers. The schools vary widely in size and quality – from one-room bush schools a days walk or more from the nearest communication with the education office to relatively well equipped urban schools servicing 400 students or more. Most schools fall somewhere in between though instructional materials (books, aids, duplicating facilities, etc.) are universally in short supply.

Children generally begin school at age 7. Slightly more than 50% of the school-age children are enrolled at any given time. The ratio of in-school/out-of-school cohorts decreases with age. The primary limiting factor to enrollment seems to be walking distance to school though many children walk up to two hours each way. Though the system is unable to accommodate all those interested in attending, there does appear to be a trend toward diminishing demand as communities become more frustrated with the lack of available post-primary educational facilities. Though the goal of community schools is commendable, vestiges of the colonial academic model seem to persist. The debate between proponents of universal primary education and those who would expand current secondary programs will continue as will their competition for limited resources and personnel.

INDIGENOUS MATHEMATICS PROJECT

The original goal of the Indigenous Mathematics Project was to assess contrasts in cognitive development, catalogue indigenous counting systems and document measurement and classification techniques at representative sites throughout Papua New Guinea (Lancy, 1978). Currently we are engaged in the second phase of the Project – the development and evaluation of student materials, instructional aids and teacher guides which are culturally sensitive and reflect the practical constraints of community-school teaching.

Since 1965 several major mathematics curriculum revisions have taken place. Zoltan Dienes provided initial guidance for the development of a modern course of study based on his multi-embodiment theory of concept development. This ten year effort produced the short lived kit-based TEMLAB program which finally resulted in the current Mathematics for Community Schools (MaCS) syllabus and teachers' guides. The implementation of TEMLAB, though seemingly well conceived, proved to be an overwhelming logistic problem considering the difficult climate and transportation conditions in Papua New Guinea. It is also apparent that the local infrastructure could not cope with the demands for teacher inservice for the highly interactive program.

IMP is currently carrying out an evaluation of MaCS curriculum materials using local teachers as participant observers. We feel it is imperative that local teachers be intimately involved in all aspects of the IMP effort and address this need in two ways. First, two community school teachers have been working with the project as research assistants since its inception. Their involvement is in no way cosmetic. They have each participated in special research and development training courses through the University of Papua New Guinea. Each has first hand involvement in site and teacher selection, data collection and curriculum development activities.

The second factor involves teacher participation in the study from five sites throughout Papua New Guinea. Two teachers from each site were invited to participate in a two week inservice workshop during their April vacation. All volunteered to attend and to participate actively in our evaluation of the current mathematics program.

The Study

In order to maximize the potential feed-back we would receive relative to specific content and design factors we opted for a quasi-experimental design utilizing a limited number of sites. At this preliminary stage we are far more interested in documenting significant classroom events than achievement gains. We have gone to considerable effort to place a well trained classroom observer at each site to take field notes of the implementation activities and interview the teachers and students. We are also collecting extensive information on cognitive development and mathematics achievement. A community school ethnography is being developed for each site as well.

The primary purpose of the study is to assess the effect on achievement of supplying selected teachers with adequate instructional materials, aids and a detailed teachers' guide along with two weeks of inservice training. These conditions have not been adequately met throughout the implementation of the current MaCS program. Also developing additional student materials (activity sheets and manipulative aids) afforded us the opportunity to alter elements within the current curriculum which, for practical or theoretical reasons, seemed out of place. For example we reduced the stress of multibase arithmetic since appropriate manipulatives have never been supplied to the schools as originally intended.

Materials: Approximately 40 lessons have been developed for each of grades 2, 4 and 6. These lessons have been adapted from Term-3 activities suggested in the current MaCS syllabus. Developmentally structured base-10 number-operation activities have been added (Souviney, Keyser and Sarver, 1977). The materials also reflect changes in content, such as de-emphasis in logic and relations.

Student activity pages have been developed and supplied in sufficient quantities to ensure that each student in the study has his own copy. Each activity sheet provides pictures and instructions to help students work through the lesson. The materials are not designed to be consumable. The students copy the exercises into their practice book or use squared paper. A minimal set of learning aids have been developed to be used in support of the student lessons and booklets. Each learning aid has been designed in such a way that it can readily be produced at the UNESCO/Department of Education Centre for the Production of Materials in Port Moresby and easily distributed. Each site has been supplied with the following materials:

1. Student Activity Booklets (one per student)
2. Teacher's Notes (two sets per school)
3. Learning Aids:

    a. Base-10 Materials (units, 10-rods, 100 rafts; punched card – 50 sets per school)
    b. Kina Cards (attribute cards – 40 sets per school)
    c. Coins (2 cards – 40 sets per school)
    d. Wooden Cubes (dice – 20 per school)
    e. Pan Balances with mass-pieces (5 sets per school)
    f. Metre Sticks (8 per school)
    g. Trundle Wheels (4 per school)
    h. Squared Paper ($1cm^2$ – 30 sheets per student)

Sites: Five Community Schools are participating in the study. Considerable cognitive, achievement and ethnographic baseline data has been collected at each site over the past

several years through the efforts of the Indigenous Mathematics Project and the Research Branch of the Department of Education. The sites range from remote-rural to urban schools and are representative of highland and coastal cultures.

IMP SITES

1. Andra Community School, Manus Province (Rural)
2. Divanap Community School, West Sepik Province (Remote-Rural)
3. Kero Community School, Southern Highlands Province (Rural)
4. Muglamp Community School, Western Highlands Province (Semi-Rural)
5. Ororo Community School, National Capital District (Urban)

Two teachers from each site were selected to participate in an IMP sponsored inservice course. The two week workshop was held at the Port Moresby In-service College during school vacation early in April, 1980. One teacher from each school was subsequently selected to implement the pilot materials in grades 2, 4 and 6 beginning 14 July.

A trained observer has been assigned to each site to collect cognitive development and achievement data, monitor the teachers implementation efforts and document a range of classroom events. These IMP Research Associates are currently monitoring activities at each site and will remain at the school sites for approximately two months (July and August, 1980).

Field Note Organization: Detailed field note guidelines have been developed and field tested to maximize data collection consistency across sites in order to minimize difficulties associated with subsequent analysis (Levin, Gearhart and Souviney, 1980). The body of the field notes are divided into three sections:

A. Preliminary Teacher Interview
B. Classroom Activity Record
C. Debriefing Interview

The research schedule calls for interviewing teachers both before and after each lesson. These are called the preliminary interview and the debriefing interview respectively. A Classroom Activity Record is developed during each lesson according to predetermined criteria.

A. Preliminary Interview

The preliminary interview has three parts:

1. Teacher's questions and comments.

The interview is initiated by eliciting from the teacher any questions or comments that he has about the lesson for the next day. We attempt to be non-directive here. We ask questions like the following, "What do you see as unclear in tomorrow's lesson? What do you think of the lesson? What can we add to the instructions to make it easier for other teachers to do this lesson? How might we make these instructions more clear for an inexperienced teacher?"

2. Narrative.

The second part of the interview is a discussion of the comments and questions that are

brought up. We respond to and assist the teacher at this point, but try not to take over, or plan the lesson for them. At the end of the narrative description, we summarize the session. (E.g., X found the instructions here vague – or, X thought he understood the instructions, but upon discussion he realized that he was unsure of the purpose of the lesson.)

3. Comments.

The third part of the preliminary interview is very important for later analysis of the field notes. While the second part is a fairly straightforward narrative of discussions with the teacher (questions asked, decisions made, changes made, etc.) this third section contains reactions to, and comments on, the interview. In this section we record reactions to and **cummulative** analysis of the teacher's interaction with the curriculum. (E.g., X appears less anxious about modifying the curriculum, – or, X is starting to express dissatisfaction with the lack of direction.)

B. Classroom Activity Record

Four categories of classroom observation field notes are described each of which constitutes a Classroom Activity Record:

1. Curriculum Implementation (CURR)
2. Language Use (LANG)
3. Classroom Interaction (CLAS)
4. Student Interview (STU)

Detailed Curriculum Implementation field notes are being taken for approximately three lessons per week for each grade level. **Summary** Implementation notes are prepared when the schedule calls for a detailed account of Language Usage, Classroom Interaction, Student Interview (one lesson per grade level per week) or for Optional Lessons.

1. Curriculum Implementation Field Notes.

a. Each session begins with an **Introduction** comprised of the following items:

i If there are changes from the usual classroom arrangement, draw a new classroom map and seating chart.
ii A list of who is present and absent.
iii A description of the transition into lesson – (What were students and teacher doing prior to lesson?)
iv A description of the transition out of lesson – (What will the students do after lesson?).
v General comments – e.g., Everyone's excited about the lesson today. The teacher seems anxious. Everyone seems bored . . .).

Field Notes: There are two versions of these field notes. For those lessons selected for Curriculum Implementation, we make detailed notes. For those lessons selected for Language Use, Classroom Interaction or Post-Lesson Student Interviews, we write only general implementation summary and comments.

b. **Detailed Notes on Curriculum Implementation:**

While observing the lesson an ongoing narrative is developed of the teacher's procedures for doing the lesson and the students' response to the lesson. The narrative is factual and descriptive. Particular attention is paid to any problems the teacher and/or students may be having relative to any changes in procedure different from that which the teacher said he would do in the pre-lesson interview. The basis on which the teacher moves from step to step in the lesson is also noted: does the teacher make an effort to assess the students' understanding before moving on to the next step or does he primarily direct the students through the steps in sequence? If he does assess the students' understanding, does he modify the lesson to help the children understand?

Noting the teacher's modification provides ideas for changes needed in the lesson. For example, if the teacher simply directs the children through the sequence, could it be because the students understand every step readily or is it perhaps that the students don't understand the lesson well at all and the teacher's concern is to just "get them through it".

Summary and Comments: Immediately after the lesson, the notes are reviewed and Summary and Comments sections are prepared. The teacher's use of materials is summarized and any problems encountered along with students' responses to the lesson are noted.

Comments are more comprehensive. They are cummulative in that they make note of any changes in the teacher's methods for the current lesson as compared to previous lessons observed. They are reflective. They suggest ideas for changes in materials or procedures that would result in a more effective lesson. The Comments become richer over time as we observe more and gain a clearer sense of which aspects of the curriculum are more successful, which are less successful, and how the teacher, the nature of the school, and its particular surroundings have influenced the success or failure of the curriculum. The Comments section is a place to interact with the field notes, a place for the observer to have dialogue with himself about his notes.

2. **Language Use.**

Language Use Form is used to document the classroom contexts in which English, Pidgin or Tok Ples (local vernacular) is used. We observe classroom events with a focus on when and how each language is used, coding for each language shift, the current classroom organization, lesson phase, time, language, speaker, addressee, interactional function and lesson function.

a. **Classroom Organization.** This category describes the participant structure in the classroom.

Cl Teacher working with the class as a whole.
Gr Students working in small groups.
Pr Students working in pairs.
Ind Students working individually.

b. **Lesson phase.** This category describes sequential phases of the lesson.

Intro – Introduction of lesson: teacher explains concepts, outlines activity.
Act – Activity: activity, worksheet, game.
Disc – Discussion: discussion after activity.

c. **Time.** Time at which each particular language shift occurs.

d. **Language.** Language use has shifted to:

E – English
P – Pidgin
T – Tok Ples (local venacular)

Speaker:

T – Teacher
Cl – Class (all together)
Gr – Group (small group all together)
Pr – Pair (pair together)
Ind – Individual student (use name if possible)

Addressee (s):

T – Teacher
Cl – Class
Gr – Group
Pr – Pair
Ind – Individual student (use name if possible)

Interactional function:

Inf – Informing, telling about; speaker wants listener to listen.
Qu-O – Open question; speaker wants listener to explain.
Qu-C – Constrained question; speaker wants listener to answer specific question.
Dir – Directing, ordering; speaker wants listener to do an action response.
Ans – Answering a question.
Eval – Evaluating an answer (e.g. "That's right", "Not exactly". . . .).

Lesson Function:

Les – Lesson talk; talk that accomplishes the maths lesson, talk about the concepts, algorithms, procedures, rules of the game, answers to problems.
Org – Organizational talk; talk about materials, seating grouping, turn taking (e.g. "who has finished?" "Who would like to come to the board?"); behaviour.
Irr – Irrelevant; side remarks (about weather, gossip, you etc. ...).

3. Classroom Interaction

The purpose of audiotaping and taking field notes on classroom interaction is to document student participation and teacher evaluation of mathematics activities in each classroom.

Eventually a detailed transcript will be produced from each audiotape for subsequent micro-analysis (Mehan, 1979).

In classroom, approximately one lesson per week per grade level are audiotaped and simultaneously coded for type of speech events and evaluation procedure. Pilot audiotapes were made at least once before the first scheduled lesson to determine optimal recorder placement in the classroom.

Coding Classroom Talk: The following structure has been developed to assist with coding classroom interaction events. A coding form is used to standardize the collection format.

A. Teacher structures interaction.

1. Open invitation to bid.

a. Chorus (more than one spontaneous respondent)
b. Callout (one spontaneous respondent)
c. Teacher selects (individual or sub-group)

2. Individual nomination.

B. Students structure interaction.

Teacher Response Type:

1. Answers question.
2. Ignores question.

C. How does the teacher give feedback (evaluate) correctness/incorrectness of academic work.

1. Positive evaluation.
2. Negative evaluation.
3. Teacher redirects evaluation to student(s).

Summary and Comments: At the end of the class period, **Summary and Comments** are written. Patterns of student participation and turn-taking procedures are summarized as well as the teacher's formulation of turn-taking rules and prohibitions, (i.e., "Everybody is supposed to raise their hands." "Don't call out." "Everyone answer together.") How is the teacher structuring small group and pair interaction? For example:

1. Does the teacher select a leader or ask the students to select a leader?
2. Were the students supposed to work out a plan on their own?
3. How did the students organize subsequent interactions?
4. Do the students call to the teacher for help?
5. Does the teacher supervise?

The teacher's procedures for ongoing academic evaluation are summarized as well. For example:

1. Does the teacher note errors in order to diagnose children's understanding/misunderstandings?

2. Does the teacher note errors and then work with the child to help with any misunderstandings of concepts, tasks and algorithms?
3. Does teacher ask children about processes and procedures (i.e., "How did you . . .?" "Why is . . .?" "What if . . .?" questions) that require reflection and analysis.

Comments are made on observed changes over time, differences across grade levels and other general impressions.

A rough transcript is prepared later using the audiotape. The teacher and/or student (they know names and voices) help identify the speaker, addressee, at least a few initial words of speaker's turn. Essential nonverbal and off-tape narrative that decribes non-audible events is documented in the narrative column to help interpret the talk at a later time.

4. Post-Lesson Student Interviews

Interviews with a 'top' and a 'bottom' student from each class will be conducted after selected lessons (approximately one per week per class). The teacher was asked to suggest high and low achieving students who would be responsive and insightful. Papua New Guinean children seem to be generally quiet in situations like these, so we have attempted to select children who seem comfortable and interested in talking about their maths work. A local translator helps with younger children as necessary.

Outline for Student Interview

a. The child is asked to describe what went on in the lesson. Interviewers are requested not to ask leading questions.

b. We probe the child's understanding of the specific activity and the underlying concepts. Can the child generalize to similar activities.

c. The child is asked to show the interviewer or someone else (perhaps another child not in the class) how to do the lesson activity.

C. Debriefing Interview

After each lesson the teacher is debriefed. That is, we attempt to find out how the lesson went from his point of view. This debriefing normally occurs in the evening, just before the preliminary interview for the next day's lesson. The interview generally includes the following questions:

i. How do you think the lesson went?
ii. Was there anything unexpected that happened in the course of the lesson?
iii. Were there any changes that you made during the course of the lesson?
iv. Would you do the lesson differently next time?
v. Do you think that the students understood the lesson? How do you know?
vi. Are there modifications that can be made in the curriculum or in the instructions that would help other teachers with this lesson?

In Summary: Field notes for each day contain:

A. Preliminary Interview

1. Teacher Questions and Comments
2. Narrative
3. Comments

B. Classroom Activity Record

1. Curriculum Implementation
   a. Introduction
   b. Detailed Field Notes
   c. Summary Field Notes (with LANG, CLAS, STU, OPT)
2. Language Use
3. Classroom Interaction
4. Student Interviews

C. Debriefing Interview

Achievement tests will be given at the end of the six weeks implementation period as well as six weeks later to measure retention. A multilevel analysis of statistical, coded and ethnographic data is planned. Collecting a balanced array of data of a summative (achievement) and formative (detailed record of ongoing implementation activities) nature, ensures a more complete documentation of the complex factors potentially associated with the relative effectiveness of the pilot materials and instruction. It is anticipated that such a design will not only be sensitive to change in student performance, allowing us to investigate interactions between cognitive development and achievement (Souviney, 1980; Hiebert, 1980) but will also offer insight into possible underlying causes of such variation in student achievement.

The results of the study will inevitably lead to specific recommendations relative to the content and design of future mathematics instructional metrials in Papua New Guinea. A preliminary report detailing our results and recommendations should be available by February, 1981.

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THE INDIGENOUS MATHEMATICS PROJECT: AN OVERVIEW

Paper Presented at the
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THE INDIGENOUS MATHEMATICS PROJECT: AN OVERVIEW

Implementation of a "modern" education system in Papua New Guinea was begun only two decades ago. Nevertheless, this period has seen several shifts in emphasis, most recently to a concern for the quality of education outcomes (Lancy 1979a, Rogers 1979). Since outcomes are not monitored directly, concern arises from two indirect indicators. First, there is growing social unrest due to various group's (there are 700 language groups in Papua New Guinea) disproportionate share of jobs in the (government–dominated) wage–employment sector. This disparity is at least partly due to the superior performance of said groups in school at all levels (Lancy 1980a). Selection for further schooling beyond grade 8 is based on merit and the ethnic diversity of the education system beyond this level is, as a result, sharply reduced. Second, even those who do "well" at lower levels of the education system fall far short of having the requisite skills to master the complex intellectual (in particular mathematics and science) demands made on them in university and technical college courses. As the country is engaged in a concerted effort to implement the most modern and sophisticated production, transportation, and communication facilities, this situation leads to a drastic shortfall in the availability of native technicians (Lancy 1980b). There is no shortfall in the number of school-places or entrants, however, the government and the students are well aware of the growing number of graduates in non-technical fields who cannot find jobs (Conroy 1976).

The Indigenous Mathematics Project, begun in 1976, grew out of these concerns. We did not, however, start from scratch. First, there was a body of cognitive research carried out by cross-cultural psychologists which had shown (albeit inconsistently) that intra-national variation in cognitive development might be a factor in accounting for the poor school performance of some groups, especially when scores were compared to western norms (reviewed in Shea 1978). Max Kelly, a prominent participant in this research, even went so far as to suggest a link between variation in cognitive development and variation in indigenous mathematics systems, in particular, in counting systems (Kelly 1971).

Second, given the overriding concern with modernization in the country's technical, commercial, and administrative spheres a great deal of attention had been paid to mathematics instruction, particularly in the elementary grades. Zoltan Dienes himself was directly involved in the creation of PNG's first modern mathematics course and subsequent versions of the curriculum have all followed closely his guiding light (Roberts 1978).

Our concerns then were to pursue the issue of cross-cultural variability in cognitive development and to study the child's acquisition of modern mathematics. Both problems were attacked on several fronts (Lancy 1979b).

We constructed a battery of five cognitive tests drawn from the work of Bruner, Cole, Piaget and their associates (Bruner et al, 1966; Cole et al, 1971; Piaget et al, 1960). The tests were designed to be adaptive to a variety of settings. Most employed local materials and all were administered in the vernacular. A test of counting ability was also included to study the possible influence (following Kelly's suggestion) of the highly varied counting systems found in Papua New Guinea (Lancy 1978a). These tests were administered to children in ten societies chosen to provide a maximum degree of contrast in life-ways and indigenous logical systems. Other sites were later added to probe for the effects of malnutrition, social class, and urbanization. In the initial sites samples were selected so that varying levels of age and education might be represented. A preliminary report prepared in 1978 (Lancy 1978b) indicated that major effects of culture and education could be expected, age, social class and urbanization were less potent and malnutrition effects were nil. No

direct link between counting systems and cognition was found but connections to indigenous classification systems were (Lancy, in prep.; Lancy and Strathern, nd).

Concurrent with the cognitive testing we also carried out extensive ethnographic research on indigenous logical systems (Biersack, 1979; Cheetham, 1978; Kettenis, 1978; Pumuye, 1978; Carrier, 1979) and child development (games—Roleasmalik, 1979; numerical reasoning—Saxe, in press a,b). This in support of our attempts to break down the "culture" variable into parts which have some validity as possible "causes" of cognitive variation and as models for the indigenization of the primary mathematics curriculum.

By late 1977 we had begun the implementation of a comparative study of mathematics classrooms (Roberts, 1978). An achievement test for primary mathematics was developed for the first time and administered in a nationwide sample of schools which included most of the sites in which cognitive testing had been conducted. A smaller number of schools was selected for intensive study which included classroom observation, material inventories and teacher preparedness surveys (Roberts and Kada, 1979). The results of this work are only now undergoing analysis and write-up (Roberts, in prep.) but some preliminary findings of interest can be reported here. First, variation in mathematics achievement across schools is enormous as we had expected. The relative performance levels of children from sites previously surveyed for cognitive skill development conformed fairly closely to the order predicted from a knowledge of those earlier results (Lancy and Kada, 1979). Nevertheless, "quality of instruction" emerged as a possibily more powerful (if more elusive), variable. Research is now underway in Phase II of the Indigenous Mathematics Project to probe further the links between cognition and the development of mathematics skills; to attempt various instructional "remedies" for the cognition/mathematics "deficits"; and to improve the "delivery" system (Souviney, 1980a).

I would like, briefly, to anticipate some of our conclusions (Lancy, in prep.) regarding the relationship between cognitive development and mathematical skill development. Piaget, in a series of publications (1952; Piaget; Inhelder and Szeminska, 1960; Beth and Piaget, 1966) has made it clear that, in his view, the cognitive operations characteristic of the concrete operational stage must make their appearance before and in support of mathematical reasoning. Indeed the ("new") mathematics curriculum in Papua New Guinea explicitly accepts this arrangement in offering extensive training in logical classification in the early grades. Piaget's formulation has not gone without challengers, notably Brainerd (1979). There is empirical evidence which supports Piaget's position (Hood, 1962; Steffe, 1968; Souviney, 1980b) and evidence which can be read as disconfirming his position (Dodwell, 1962; Siegel, 1971a, b; Saxe, 1979a). Our findings would appear to fall in this latter category. In general, we find that basic number competence develops with few surprises. Counting skills appear somewhat later than they do in the West but develop through the same series of stages (Saxe, 1979b in press a,b—Saxe and Lancy, nd). Our testing of basic arithmetic skills (Roberts and Kada, 1979; Lancy and Kada, 1979) shows a similar trouble-free development and there appears to be little intra-cultural variation in these skills. At the same time, cognitive development appears to deviate sharply from western norms at least in some societies. Conservation of number, mass and seriation appear very late if at all (Saxe and Lancy, nd.) and conservation of length (Lancy, Souviney, and Kada, nd.), logical classification and class inclusion (Lancy and Strathern, nd.) are achieved by less than half the population through adulthood. Thus basic numeracy appears to be totally unrelated to cognitive development (at least in Piagetian terms). On the other hand, there is the very likely possibility that skills beyond counting, addition and subtraction are poorly developed because pupils from some societies are still functioning at the pre-operational level.

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FOURTH INTERNATIONAL CONGRESS ON
MATHEMATICAL EDUCATION

Berkeley, California, USA
10 - 16 August, 1980

PAPUA NEW GUINEA
Secondary Mathematics - a curriculum development project

Presented
by

Murray Britt
UNESCO Specialist in Secondary Mathematics

PAPUA NEW GUINEA

Secondary Mathematics – a curriculum development Project

Murray Britt

BACKGROUND

The pace at which provision for the secondary education of Papua New Guineans developed in Papua New Guinea between 1964 and 1973 exceeded all projections and indeed was nothing short of phenomenal. In 1962, 444 boys and 47 girls were enrolled in secondary schools. By 1973, total Papua New Guinea enrolments had surpassed 26 000. By 1980 this figure had grown to 37 000.

In 1967, the secondary teaching force was an expatriate one. The first Papua New Guinea graduates from the only secondary teacher training institution – Goroka Teachers College, didn't appear in schools until 1970. The table below shows how few Papua New Guinean secondary teachers there were even by 1973.

Year	Goroka Graduates
1970	28
1971	49
1972	48
1973	86
	211

This year, 1980, the secondary teaching force numbers approximately 1 600, of whom 1 000 are national officers. Although 1982 has been set as a date for full localisation, it is likely that this date will be extended by 2 to 3 years.

SYLLABUS DEVELOPMENT – PRE INDEPENDENCE

The first official syllabus for secondary schools appeared in 1967. It comprised 27 pages and included most of the ideas that one could find in a comparable Australian syllabus of the time. There was an emphasis on sets and set language, on algebra with equations and inequations and on transformation geometry. There were no notes for the teacher other than the brief comments included in the syllabus.

By late 1970 it had become apparent that new and even experienced expatriate teachers needed more guidance with the content they were being asked to teach. A new issue of the syllabus was prepared and distributed for use in January 1971. Although this new syllabus contained the same content as the 1967 edition, it did provide many more notes for teachers. There was still a major emphasis on sets and logic and indeed the syllabus contained a glossary of terms and detailed explanations of these terms. Here is an extract from this glossary.

CONTRAPOSITIVE

The contrapositive of the statement

$p \rightarrow q$

is the statement

$\sim q \rightarrow \sim p$

formed by negating each of the statements p, q and then forming the converse.

It may be shown using truth tables that a conditional statement and its contrapositive are always equivalent.

For example:

let p ≡ It is a dog

and q ≡ It is an animal

Then $p \rightarrow q$ ≡ If it is a dog then it is an animal.

The contrapositive is therefore

$\sim q \rightarrow \sim p$ ≡ If it is not an animal then it is not a dog.

Upon a little reflection, it should be evident that

$p \rightarrow q \equiv (\sim q \rightarrow \sim p)$ at least in this case.

It is extremely doubtful whether any Goroka graduate would understand any of this. Clearly in 1971 there was no recognition given to the standard of English proficiency attained by Papua New Guinean teachers for whom English at best is a second language, but for many is a third or even a fourth language. (There are some 700 different language groupings throughout the country and although English is the official language, the lingua-franca is predominantly Pidgin-English, known as tok-pisin.)

Some educators were quite dissatisfied with the kind of mathematics included in the syllabus, and in 1972, a group of expatriate teachers and teacher educators from Goroka, developed an alternative syllabus for grades 7 and 8 (then forms 1 and 2). In a sense though, this Goroka group was acting in a remedial manner because it saw its alternative syllabus as only being necessary for those pupils who had not been subjected to the recently revised primary mathematics programme.

In retrospect, it is difficult to understand why this alternative syllabus, offered by the Goroka group, didn't gain official support. Although the language may have been too difficult, the mathematics content of the syllabus was immeasurably better than that offered in the official syllabus of the time. But although it didn't gain official support, it did stimulate the production of a substantial set of notes to accompany the 1971 syllabus. This 114 page set of notes, together with a reprint of the 1971 syllabus, was distributed to all schools in 1973.

Despite the addition of this set of notes or teachers' guide, there was still considerable disenchantment with the content of the syllabus. Research conducted by staff at the Maths Learning Project based at the University of Technology in Lae, indicated that at least among

the samples they had tested, many secondary pupils and university students were not able to 'conserve' with basic physical concepts: weight, length, time, area and volume. Officials within the Department of Education, and indeed many educators within Papua New Guinea, interpreted the poor achievement among many pupils and students as being directly related to the findings of this MLP research work.

As a consequence, a new draft syllabus was prepared and distributed for trialling in 1975. A feedback questionnaire was also issued in 1975 and it is at this point that teachers and Department of Education officials began preparations for a major initiative in secondary mathematics curriculum development.

Curriculum development activities in Papua New Guinea were at their infant stages even in 1975 when a Curriculum Unit was established within the Department of Education. To that date and indeed beyond, curriculum development was perceived as providing schools, firstly with syllabuses, and where possible, with teachers' guides. The development of pupil learning material was seen as being the responsibility of the individual teacher, thereby promoting a professional growth within the teacher concerned. This notion was imposed from a foreign source and really indicates how little was understood about the nature of the already severe demands placed on a teacher who has little educational background – at least in a schooled sense – and for whom English is a second language.

Despite these limits, imposed as a result of Papua New Guinea's recent historical development, it was decided to recruit a curriculum specialist, through UNESCO, to be funded under the auspices of the United Nations Development Programme (UNDP) to write new syllabuses which would take cognisance of the MLP research.

SYLLABUS DEVELOPMENT – POST INDEPENDENCE

In 1975, the Department of Education established a Syllabus Committee with an advisory role to the Secretary for Education. The 1975 draft syllabus was discussed at a meeting of this Committee in November 1975, and a new syllabus for grades 7 and 8 was subsequently developed. The major modifications agreed upon were: the deletion of sections on algebra and transformation geometry and the inclusion of a section which emphasised pattern, and an additional piece of social mathematics – communications. (The draft already included a substantial piece of commerical arithmetic.)

The UNESCO specialist's role in the development of this new syllabus was to write the syllabus objectives in behavioural terms, to include teaching suggestions for each objective and to ensure that by January 1976, the syllabus was printed and distributed to all secondary schools (80 at that time). The syllabus distribution deadline was met but the document had grown from a 21 page draft to a 200 page syllabus/teachers guide.

In May 1976, a syllabus/teachers guide for grades 9 and 10 was prepared by the UNESCO specialist following a Syllabus Committee meeting. This new syllabus which was written in a similar style and format to that of the grade 7 and 8 syllabus, was issued to all schools in 1976 for a 2 year trial period. In July 1978, a 'final' edition was formulated by the Syllabus Committee following consultation with personnel from post-secondary training institutions including: The Port Moresby Technical College, Steamships Trading Company, and The Electricity Commission. These institutions receive grade 10 graduates into their training programmes, the development of which is heavily dependent on the background and achievement of students entering the institutions from Provincial High Schools. It is therefore fair to say that each of these post-secondary institutions influenced the mathematical content

included in the syllabus for grade 9 and 10.

STRATEGIES FOR CURRICULUM DEVELOPMENT

The two most commonly described strategies for curriculum development are the: research-development-dissemination (RDD) mode and the periphery or local development mode. The two modes are fixed at the two ends of the curriculum development continuum. The RDD mode uses a specialist or team of specialists to write and trial curriculum materials, making full use where possible of relevant research publications – this is seldom done – and then to disseminate the materials to the users – teachers and children.

The periphery mode accepts that the curriculum is really a description of the learning aids that exist within the classroom, and how these learning aids interact with the children as the learners. There is acceptence that the role of the teacher as a learning aid is a major one and is a vital one. The periphery mode uses teachers themselves to write, trial and develop their own curriculum materials.

It would seem quite natural, and indeed it was, for Papua New Guinea to adopt the RDD mode when embarking on a curriculum development project. The educational background of almost all teachers was minimal; English language proficiency was minimal; and there was virtually no previous experience of curriculum development from which lessons could be learned. It made sense, therefore, to recruit curriculum specialists externally, to base these specialist centrally, and to adopt the RDD model.

DEVELOPING TEXT MATERIAL

Following the distribution of the new syllabuses/teachers guides to all schools in July 1976, short workshops were conducted throughout the country in an effort to properly establish the new programs.

At these workshops, teachers in all areas described their most urgent need as having text material based on the new syllabuses and which was both relevant and appropriate to the Papua New Guinea situation. Relevant meant mathematics derived from the Papua New Guinea environment and which could be used to solve everyday problems. Appropriate, meant mathematics matched with the cognitive development of the individual Papua New Guinean pupil.

At the same time, a survey conducted by Dr. N. Roberts of the University of Papua New Guinea, revealed that the majority of teachers throughout the country felt that the supply of text material was a priority need.

A proposal to produce text material in the form of sets of booklets was subsequently developed and included a production schedule as well as details of production costs. These costs are shown in the table below.

Grade	Sets of booklets required	Number of booklets per pupil	Mean no. pages per booklet	Total no. of booklets	Cost per pupil	Total cost
7	15 000	17	20	255 000	85t	K12 750
8	15 000	15	20	225 000	75t	K11 250
9	8 000	17	20	136 000	85t	K 6 800
10	8 000	12	30	96 000	90t	K 7 200
				712 000		K38 000

Distribution costs were estimated at *K22 000, bringing the total cost of the project to K60 000.

It is worth noting that if the Department were to purchase text books from an overseas publisher at a unit cost of say K5.00 per book, the total cost including distribution would be in excess of K300 000. For such a purchase the Department of Education would receive texts that were neither relevant nor appropriate for Papua New Guinea pupils.

The production of booklets rather than a single volume text was decided upon for 3 reasons.

1. To allow for flexibility with their use.

2. To permit easy modification subsequently.

3. To allow for printing. The UNESCO Printshop which had been extended at Goroka Teachers College under a UNDP/UNESCO Project would be responsible for printing more than 700 000 booklets. The Printshop facilities could just cope with a 15 000 run of a 20–30 page booklet, but was quite unable to cope with the printing and collation of 15 000 copies of a 400 page text.

Clearly, there was no other choice but to produce booklets, although it was noted at the time that there would be problems of storage and organisation within the classroom to be overcome. An earlier social science project which produced similar kinds of material – in small packages rather than one large text – had encountered major organisational difficulties at the classroom level.

At this time, the Department of Education still considered that the central development/dissemination model was the only strategy that might meet with success, and so requested UNESCO/UNDP assistance to write, trial, edit, print, and distribute the booklets to secondary schools throughout Papua New Guinea. The specialist would be required to work in close consultation with the Syllabus Committee and with the Maths Learning Project (MLP) which was about to change its identity to The Maths Education Centre (MEC).

Material for grade 7 was prepared during the latter part of 1976 and in 1977, and trialled in four 'pilot' schools located in the highlands region. Schools in the highlands region were chosen because children at these schools were least advantaged in an historical sense, and because all the schools were accessible by road from Goroka Teachers College where the UNESCO specialist was stationed. The pilot sample was limited to four in number because a sample of this size allowed the trial to be carefully monitored through classroom observation, teacher reaction and more importantly, how pupils actually respond to the materials. It was realised however that such a small group of 'pilot' schools would not reveal all the problems that inevitably arise when materials are more widely disseminated. For this reason, comments regarding design, language usage, and content were sought and obtained from a variety of sources within and from outside Papua New Guinea.

DESIGN AND PRODUCTION

Most teachers throughout Papua New Guinea have had a very limited mathematical background. This fact, coupled with the low level of English language proficiency among teachers in general, meant that the project materials could not assume that examples would provide sufficient cues for the teacher to teach the various ideas prescribed in the syllabus. Nor would

* (At the time of writing, 1 PNG Kina = US$1.51.)

inclusion of teaching material within a guide be satisfactory. Such guide material would assume that the teacher could understand and internalize the ideas, formulate the ideas in his own words, and subsequently teach the same idea that was initially presented. All too often, this process has been shown not to work with a garbled misinterpreted message reaching the pupils.

The booklets therefore were written for use by both teacher and pupil together. Sections that required teaching were headed READ THIS. The teaching notes under this heading were written in simple English so that they could be used for immediate and future reference by pupils and teachers.

Here is an example of a page from a booklet on measurement of length.

READ THIS

Before you measure anything, it is a good idea to try to estimate the measurement.

When we estimate a length, we think about the length. (We try to guess the length.)

ACTIVITY 2

You will need: Your paper handspan, pencil and your exercise book.

WHAT TO DO

1. Look around your classroom and choose 5 things to measure.
   Here are some things that you can choose.

The philosophy behind the development of the mathematics in the booklets can be described in the following way.

> Doing mathematics is really an exercise in thinking. It's about solving problems. When a child does mathematics, he needs to express his thoughts and ideas not only on

paper, but in discussion with his friends and his teacher. An essential part of doing mathematics is communication. Teachers guide their pupils, who in turn, are expected to respond to that guidance.

The Papua New Guinea secondary mathematics curriculum project uses the structure: guidance, doing, thinking, and communication as its principal methodology. Many activities are included in each booklet or unit. Some activities require groups of two pupils, others need larger groups of four, and some activities can be done alone. But each activity requires: teacher guidance, pupil activity, time for thinking, and time for communicating. Pupils will obtain greatest benefit if teachers ensure that these critical functions are included in their lessons.

Some things in any mathematics program have to be learned and remembered, and pupils will not remember unless they practise. Practice, or drill, can take many forms: doing exercises, playing mathematical games, writing and saying repeatedly, and so on. The use of a single drill method may seem dreary to many pupils and may not produce the desired effect. For this reason, drill games, which it is hoped pupils will find both enjoyable and challenging, have been provided in places where remembering is essential.

Pupils and teachers alike usually want to know how well a piece of work has been understood and mastered. A CHECK TEST has therefore been included at the end of most units. The test should be used to diagnose pupil weaknesses and strengths. Where weaknesses are found, it is presumed, and hoped, that teachers will provide additional work to remedy them.

A concern which has been articulated in many countries is the need to ensure that there is an integration in a methodological sense between the primary mathematics curriculum and the secondary curriculum. Because there is a project known as the Indigenous Mathematics Project (IMP) currently undertaking research and development work at the primary level in Papua New Guinea, and both this project and the secondary project come under the umbrella of a single UNESCO/UNDP project, it has been possible to systematically use a learning model that spans both areas, and which comprises three levels.

1. **Concrete level**
   Concrete models which, through manipulation, provide a clearly perceived understanding of the underlying concept.

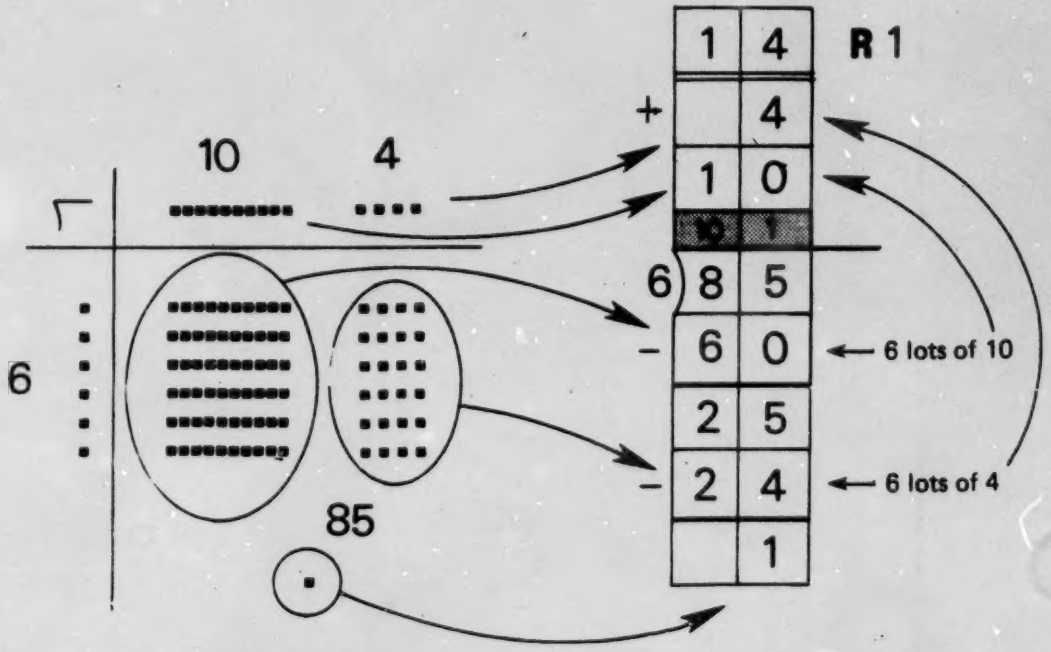
2. **Representational level**
   Graphic or concrete materials which require greater use of the imagination, in order to provide cues for understanding of the concept.

3. **Symbolic level**
   Numbers, letters, or other symbols which require abstract conceptualization without dependence on tangible models.

The relationship between primary development work and secondary development work can easily be illustrated with an example. Arithmetic concepts in primary (addition, subtraction, multiplication and division) are developed in sequence at all 3 levels. At the secondary stage, we pick up these concepts at the representational level making full use of imagery strengths which we know exist among many Papua New Guinean children. (These imagery strengths were first described by Dr. Alan Bishop of Cambridge University as a result of research work

that he conducted in 1977 at the University of Technology.) From the use of graphics and pictures we move to the symbolic level. The point, however, is that, whereas at the primary stage, the development of **these** arithmetical concepts – and the word **these** must be stressed – encompasses all 3 levels with early emphasis at the concrete level, the secondary stage begins for most children at the representational level before moving to the symbolic level. Each concept within the entire program requires a separate analysis of this kind, and subsequent development action which makes full use of the children's strengths and takes account of their weaknesses. Some secondary mathematics concepts require treatment at all 3 levels, others 2 levels and some just 1 level. But the relationships between the secondary and primary development actions must be properly understood.

Here is an example that shows the division algorithm at two levels: representational and symbolic. The placement of the two illustrations side by side helps bridge the gap between the two levels.



The picture on the left is an illustration of a dividing table or 'sharing mat' that is used predominantly within the IMP primary curriculum materials. 85 objects (base-10 material) are shared equally among 6 people. The results of this sharing activity are systematically recorded in picture form and in symbolic form.

By January 1978, all secondary schools, and indeed all grade 7 pupils, had access to the first set of booklets for grade 7. The completed set comprised sixteen booklets. The table below shows the number of booklets produced and the actual cost of production.

Grade 7 Maths Booklets

Unit	Title	Pages	Copies	Total no of pages
1	Making Patterns	12	15 000	180 000
2	Counting Systems	20	15 000	300 000
3	Working with Numbers	40	15 000	600 000
4	Number Patterns	16	15 000	240 000
5	Fractions	20	15 000	300 000
6	Decimals and Percentages	40	15 000	600 000
8	Length	24	15 000	360 000
9	Weight	20	15 000	300 000
10	Time	24	15 000	360 000
11	Area	24	15 000	360 000
12	Capacity	20	15 000	300 000
13	Angles	20	15 000	300 000
14	Number Problems	20	15 000	300 000
15	Coordinates	20	15 000	300 000
16	Statistics	28	15 000	420 000
17	Communications	24	15 000	360 000
		354		5 580 000

Proposed cost @ 5t/20 pages = K12 750
Actual cost @ 5t/20 pages = K13 950

Because more people were involved in the curriculum development activities associated with the production of the grade 8 booklets, as a result of the establishment of four Mathematics Groups (see next section), the pace of development of the Grade 8 materials slowed and although the first grade 8 units reached schools in February 1979, the last units (13 altogether) didn't reach schools until March 1980. A table showing production quantity and costs, similar to the table for grade 7, has been prepared for grade 8.

Grades 8 Mathematics Booklets

Unit	Title	Pages	Copies	Total no. of pages
1	Number Patterns	20	15 000	300 000
2	Coordinates	32	15 000	480 000
3	Fractions	32	15 000	480 000
4A	Decimals	40	15 000	600 000
4B	Decimals and Percentages	44	15 000	660 000
6	Area	36	15 000	540 000
7	Symmetry	16	15 000	240 000
8	Circles	24	15 000	360 000
9	Statistics	40	15 000	600 000
10	Volume	32	15 000	480 000
11	Similar Shapes and Ratio	36	15 000	540 000
12	Shapes and Angles	36	15 000	540 000
13	Communications	28	15 000	420 000
		416		6 240 000

Proposed cost @ 5t/20 pages = K11 250
Actual cost @ 5t/20 pages = K15 600

The Department of Education has, during the lifetime of this project, been concerned about the longevity of the booklets for which storage is a major problem, and about the classroom logistics in using the booklets. It has always felt that larger texts are more suited to Papua New Guinea where few teachers have sufficient training in using a unitized system in a flexible manner and where few schools have sufficient space and material to develop a necessary library mode storage system. Consequently, at a time when the Department was reviewing its future printing requirements, it decided to reprint the grade 7 booklets as a two-volume text.

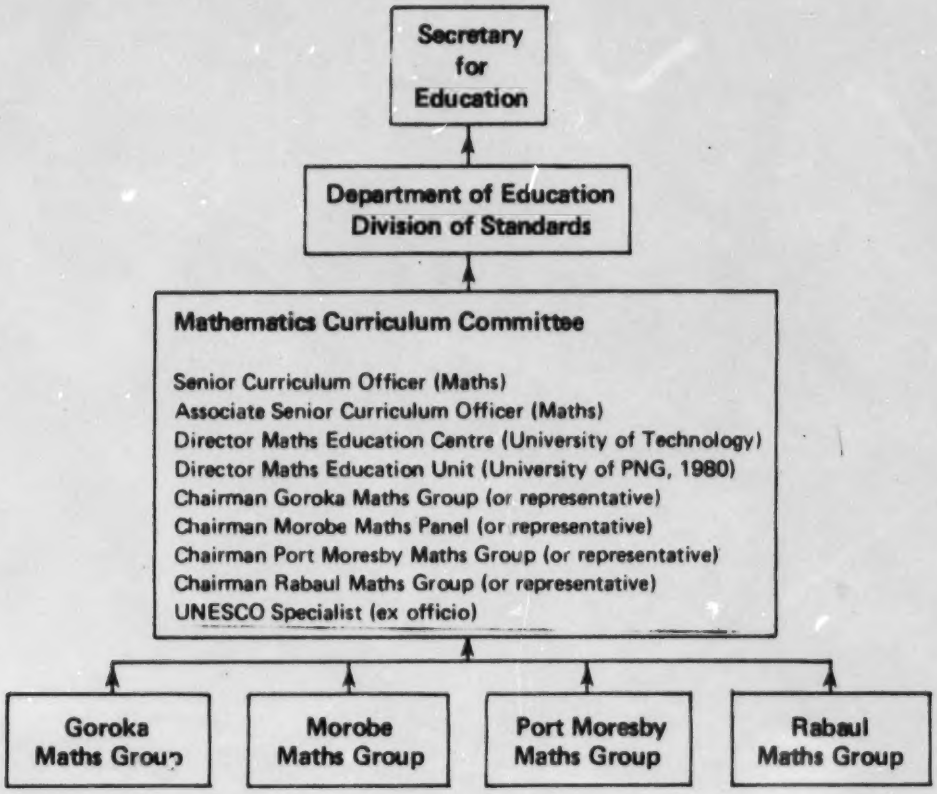
During the two year period in which the grade 7 material had been in schools, a lot of comment had been received about the content of the booklets. A major criticism, and this may have resulted from the world-wide 'back-to-basics' movement, was the insufficient emphasis that the booklets placed on arithmetical skills. When a decision was made in late 1979 to reprint the grade 7 booklets as a two-volume text, it was therefore decided to redevelop the arithmetic sections and include a greater number of practice exercises in these sections. The necessary work on the material has now been completed and the two volumes of 'Mathematics Our Way' are currently with publishers, Jacaranda Wiley.

Because the UNESCO specialist has been editing/modifying the grade 7 material for external publication, and because the development of the grade 8 material took longer than expected, the production of grade 9 material has been delayed. It is nevertheless expected that by 1982, all schools throughout Papua New Guinea will have full sets of mathematics materials for grades 7, 8, 9 and 10.

A NEW STRATEGY FOR CURRICULUM DEVELOPMENT

The adoption of a central development/dissemination model for curriculum development, together with the reasons for the adoption of this model, have been described earlier. Opponents of the central strategy are usually to be found in large numbers, particularly among teachers who so often tend to be forgotten when a central strategy is adopted. Before curriculum materials will be used in the manner in which they were intended, teachers need to be convinced of their value.

In 1978, the UNESCO specialist articulated this dissatisfaction among teachers, through a proposal to establish mathematics groups in four key Papua New Guinea centres. These centres were at Lae, Port Moresby, Goroka and Rabaul, and were selected because they were centres of major population growths, and because each centre had a higher education institution/s: university, teachers college, or national high school (grades 11 and 12), from which the initial group leadership could be drawn. The proposed structure of the groups provided for the feeding of 'grass roots' activities, ideas, and recommendations, into the national system through the administrative and consultative hierarchy shown below.


Secretary for Education
Department of Education Division of Standards
Mathematics Curriculum Committee
Senior Curriculum Officer (Maths)
Associate Senior Curriculum Officer (Maths)
Director Maths Education Centre (University of Technology)
Director Maths Education Unit (University of PNG, 1980)
Chairman Goroka Maths Group (or representative)
Chairman Morobe Maths Panel (or representative)
Chairman Port Moresby Maths Group (or representative)
Chairman Rabaul Maths Group (or representative)
UNESCO Specialist (ex officio)
Goroka Maths Group
Morobe Maths Group
Port Moresby Maths Group
Rabaul Maths Group

A feature of the Groups is their composition. It was recognised that each level of education: primary, secondary and post-secondary needed help in the form of curriculum development and in-service training. Representatives from each of these levels were consequently invited to participate in the Group activities.

By mid 1978, each of the four Groups was functioning as intended. Each Group:

(a) participated actively in the preparation of curriculum materials for both Provincial High Schools and Community Schools

(b) monitored the trialling of pupil's booklets for grade 8

(c) provided feedback and suggestions on the grade 8 trial material

(d) participated in the preparation of in-service activities within their provinces.

In October 1978, a combined Groups' workshop was held at the University of Technology in Lae. This workshop was jointly sponsored by the Department of Education and UNDP/ UNESCO and focused on: secondary curriculum development, and in-service training programs preparation for Community School teachers.

A second combined workshop was held at Goroka Teachers College in 1979 and has been documented in a report, 'Curriculum Development in Papua New Guinea – Mathematics'. In this report, much is said about the enthusiasm and enjoyment generated among workshop participants and in particular among Papua New Guinean participants. Here is a short extract from the report.

THE WORKSHOP IN RETROSPECT

The enthusiasm shown during the extended debates in the Workshop's final evening session which lasted from 7 pm to 11 pm, clearly illustrated to everyone how much stimulation and enjoyment the Workshop had provided. For many, and they said so, it was the most satisfying and exciting workshop of its kind that they had ever attended.

The Workshop represents a landmark in the development of field staff participation in the full curriculum development implementation process.

But the most gratifying feature of the week's activities was the forward position taken up by Papua New Guinean mathematics educators. The year since our last National Workshop in Lae has seen these Group members, of whom there were twenty-six out of the total of forty eight participants, mature and gain in confidence so that they are no longer seemingly content to just listen to discussions and decision making, but rather are now to the forefront in taking initiatives and playing a leadership role.

Examples of this 'new confidence' among Papua New Guinean mathematics educators have been recorded on a video recording of the main features of this Second National Mathematics Workshop.

Above: Paul Koro and Venina Kada solving a problem during the 1979 Workshop

Although the Mathematics Groups are now actively participating in curriculum development work at all levels of the education system, it cannot be said that they are writing the project curriculum materials. But it can be said that the Groups are influencing, in a major way, the design and content of those materials. We in Papua New Guinea have not adopted the periphery model for curriculum development, but have successfully moved from the central development/dissemination extreme, along the curriculum development strategy continuum, towards the 'periphery model' extreme. Because of the success of this new venture, there are

indications that other areas of the curriculum are planning similar developments in order to widen the participation in the vital process of curriculum development.

CURRICULUM IMPLEMENTATION

At present, there are some sixty teachers and educators involved in maths group activities described above. But this sample is minute when compared with the total primary and secondary teaching force which numbers approximately 11 000. Because the maths group members are not scattered widely among the total teaching force, it is impossible for the new knowledge gained by members to be widely disseminated. A newsletter, 'Mathstok' (maths talk) has been started, but newsletters seldom generate the kind of enthusiasm and feeling of involvement that have been kindled by the personal interaction within the maths group structure.

Although maths groups have conducted short in-service training courses for secondary and primary treachers, an enormous amount of training – short courses and longer institutionally based courses – is still required. Training on a massive scale is needed.

A PROJECT EVALUATION

Although evaluation is recognised by many as being an integral and vital part of the curriculum development process, few curriculum projects – usually because of financial constraints – actually include an evaluation component. Papua New Guinea has been most fortunate in this respect and has obtained the services of a British educationalist, Mr. John Hayter of Bristol University, to carry out a formative evaluation of this curriculum project's activities. The broad objectives of the evaluation are to:

(a) provide objective information on the appropriateness of the project materials to the pupils' needs and to the country as a whole, and to better enable the Papua New Guinea Department of Education to gauge and set realistic standards in mathematics education;

(b) judge how the secondary mathematics program is seen to relate to other subject areas within the curriculum and so to the pupils 'total' formal education;

(c) provide guidelines for the future development of mathematics curriculum materials including: in-service handbooks, teachers notes, and enrichment material.

It is expected that this evaluation will be completed by mid-August 1980 and a report of the work will be issued later in the year.

NOTES

IMP Indigenous Mathematics Project (Papua New Guinea 1977 – 1981)

MLP Maths Learning Project (University of Technology, Lae 1973 – 1977)

MEC Maths Education Centre (University of Technology, Lae 1977 – formerly MLP)

MEU Maths Education Unit (University of Papua New Guinea, Port Moresby, 1980 –)

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FOURTH INTERNATIONAL CONGRESS ON
MATHEMATICS EDUCATION

Berkeley, California, USA
10 – 16 August 1980

NATIONAL ASSESSMENT OF MATHEMATICS ACHIEVEMENT IN PAPUA NEW GUINEA

A background paper prepared for a panel discussion
on "Issues, Methods and Results of National
Mathematics Assessment".

by

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Department of Education
Papua New Guinea

This paper outlines Papua New Guinea's current innovative thinking and action which attempts to tackle the issue of how to achieve a sufficiently high standard of mathematics achievement to meet national development needs.

THE PAPUA NEW GUINEA CONTEXT

Papua New Guinea is a newly independent nation of three million people in the south west corner of the South Pacific. Since it gained independence from Australia in September 1975 its then expanding education service has continued to grow at a considerable rate coupled with a similarly rapid rate of localistation particularly at the administrative and primary school levels. The current (1979) enrolment statistics are given in the appendix.

A comparatively sophisticated modern sector grows daily, employing advanced technology e.g. microwave communication systems, and places heavy demands upon the limited numbers of school leavers with a sufficiently high level of mathematical education.

The Education Department seeks ways of improving standards of mathematics achievement. To date the four national examinations in Mathematics, i.e. at Grades 6, two at Grade 10 and one Grade 12, serve only to rank students for selection purposes. Very few achievement criteria are required to provide teachers and students with sufficiently high achievement goals.

The most serious outcome of low levels of achievement within the school system is the subsequent failure of Grade 10 graduates to meet the demands of further education or technical training courses into which they enter. An extreme example might be the lethal errors which could be made by a trainee nurse, with limited knowledge of the metric measurement system, being required to prepare and administer dangerous drugs.

Outlined below are our recent attempts to (a) establish what mathematics is being learned in schools and so to best judge where to place the development emphasis to assist classroom teachers in their day-to-day teaching of the subject and, (b) to set realistic achievement goals for teachers and students to work towards.

PRIMARY MATHEMATICS ACHIEVEMENT

In 1977 a small committee of curriculum developers, college lecturers and researchers was formed to develop a series of achievement tests to assess pupil performance in primary Mathematics. This development coincided with the introduction of a new Dienes-based primary mathematics curriculum, known as Mathematics for Community Schools (MaCS). The PMAT programme was to be in five phases:

Phase 1: The design of a preliminary test consisting of questions ranging the content of the whole course and for all grades.

Phase 2: The trial and analysis of the preliminary test.

Phase 3: The design of an expanded test to be in five parts. One part for each of the strands of the course:

1. Logic
2. Relations

3. Number
4. Measurement
5. Geometry

Each of the five tests was to contain questions for Grades 2 to 6.

Phase 4: The trialling and analysis of the strand tests.

Phase 5: The design of an improved batch of strand tests and the setting of grade norms of achievement in each strand of the course. Information gained during the project would enable teachers to judge better what children could be expected to master at each grade level.

To date the PMAT programme is at Phase 2.

The 50-item preliminary test was structured in such a way that the first ten items were taken from the Grade 2 objectives, the next ten from the Grade 3 objectives, and so on, so that the items 41–50 were testing Grade 6 objectives. Response modes included matching items of the same type or value, circling the answer, colouring the answer, simple computation and filling-in the answer. The PMAT has been administered late each year for the past three years to an average and representative sample of thirty community schools.

Using the criterion "proportion of their ten questions for which pupils got full marks" i.e. for Grade 6 pupils only questions 41–50 were examined, mastery levels were calculated. Table 1 shows the comparison of pupils' mastery levels by this criterion over the three years.

Table 1

Comparison of Pupil's Levels of Mastery of Mathematics Over the Years 1977, 1978 and 1979

	GRADE LEVELS					TOTAL
	2	3	4	5	6	
$\bar{x}$ ±	72.10 ±	26.37 ±	35.00 ±	10.68 ±	14.50 ±	N
1977	19.38	15.28	11.31	4.99	8.72	
n	56	59	61	55	61	292
$\bar{x}$ ±	71.17 ±	42.00 ±	32.00 ±	26.46 ±	18.60 ±	
1978	18.28	10.23	10.51	5.23	10.09	
n	70	40	65	65	50	290
$\bar{x}$ ±	71.25 ±	40.18 ±	29.34 ±	15.40 ±	18.58 ±	
1979	16.52	15.59	7.59	4.27	15.29	
n	31	41	33	31	33	169

Grade 2 pupils only are achieving a satisfactory level of mastery of their level of questions. Thereafter, mastery levels dropped rapidly. There had been no significant change ($X^2 = 3.95$, df = 4, p = n.s.) in mastery levels during the first three years following the introduction of the MaCS curriculum. It is beyond the scope of this paper to give any detailed analysis of this situation (background can be gained by reading Roberts 1978 and Roberts and Kada 1979). The course content is currently under review as part of the Indigenous Mathematics Project (Lancy 1979 and Souviney 1980) in preparation for the development of a student textbook to replace the present brief teacher's notes (the sole source of information and guidance to teachers). It may be also added that at a time when standards are said to be (as opposed to being proven to be) falling, this evidence would seem to indicate that standards have not fallen during this period of curriculum change, though they are clearly low in relation to the MaCS syllabus objectives. To date, very little information from the findings of the PMAT programme have been translated into teacher-usable information. An article reporting the findings (in broad terms) of the 1977 PMAT survey appeared in the Department of Education's Gazette in April 1979.

BASIC ARITHMETICAL SKILLS AT POST-SECONDARY LEVEL

During 1979 the Director of the Mathematics Education Centre, Lae, Mr. Allen Ewards, conducted a survey of Grade 10 graduates who had entered post-secondary education and training institutions that year. The survey aimed at identifying "the types of questions which post-secondary entrants could or could not answer correctly" (Edwards 1979:2).

A total of 2604 students and trainees, i.e. 42% of all 1978 Grade 10 graduates and 55% of those who entered post-secondary education or training institutions, were tested. The survey covered 88% of all such institutions.

The test contained 84 items of basic arithmetic ranging from simple additions of whole numbers to comparisons of decimal fractions, time telling and simple measurements.

Table 2 shows the mean scores of students in each type of institution.

Table 2

Performance of Grade 10 Students in Post-Secondary Institutions on a Test of Basic Arithmetic in 1979

Rank Order	Mean Score in Test Out of 84	%	Type of Institution	Rank Order	Mean Score in Test Out of 84	%	Type of Institution
1.	77.5	92.3	University	23.	63.6	75.7	School of Nursing
2.	75.0	89.3	National High School	24.	63.1	75.1	Teachers College
3.	74.7	88.9	Prim. Industry College	25.	63.9	75.0	School of Nursing
4.	74.6	88.8	University	26.	62.3	74.2	Teachers College
5.	73.9	88.0	C.A.H.S.	27.	61.4	73.1	Teachers College
6.	73.8	87.9	C.A.H.S.	28.	61.1	72.7	Technical College
7.	73.1	87.0	National High School	29.	59.6	71.0	School of Nursing
8.	70.1	83.5	Prim. Industry College	30.	59.1	70.4	Teachers College
9.	68.0	81.0	Prim. Industry College	31.	58.4	69.5	Technical College
10.	67.7	80.6	School of Nursing	32.	58.4	69.5	School of Nursing
11.	67.5	80.4	Prim. Industry College	33.	58.0	69.0	School of Nursing
12.	57.5	80.4	School of Nursing	34.	57.8	68.8	Secretarial College
13.	67.2	80.0	Technical College	35.	56.9	67.7	School of Nursing
14.	66.9	79.6	Teachers College	36.	56.0	66.7	School of Nursing
15.	66.6	79.3	Prim. Industry College	37.	55.8	66.4	School of Nursing
16.	66.3	78.9	School of Nursing	38.	55.0	65.5	School of Nursing
17.	65.7	78.2	School of Nursing	39.	54.9	65.2	School of Nursing
18.	65.4	77.9	National High School	40.	53.0	63.1	School of Nursing
19.	65.1	77.5	Technical College	41.	49.4	58.8	School of Nursing
20.	65.1	77.5	Secretarial College	42.	48.9	58.2	School of Nursing
21.	64.8	77.1	Teachers College	43.	36.5	43.5	School of Nursing
22.	63.6	75.7					

C.A.H.S. – College of Allied Health Science

The range of scores on what was essentially a mastery test was very wide. Edwards made a particularly strong comment about the inability of trainee nurses to do simple arithmetic and the inherent dangers when such nurses mixed and administered drugs. Serious deficiencies in the basic arithmetical skills of university students were revealed (Edwards 1979: 12–16). One disturbing example was that amongst 18 second year students tested at the University of Technology "..., who were among the cream of the nation's future businessmen, apparently could not divide K75.00 by 100 correctly, while 7 failed to multiply 18.3 by 100" (Edwards 1979: 30–31).

Concerns over low levels of achievement in basic arithmetic amongst entrants to post-secondary education and training institutions in Papua New Guinea has for some time been a matter of serious concern (note Bajpai 1971, Roakeina 1977, for example). The current concern appears widespread amongs educators in the more than sixty post-secondary institutions in Papua New Guinea today. Some of the difficulties faced by post-secondary instructors appear to result from the failure of the present Grade 10 examination system to optimise student ability at that level.

AN ALTERNATIVE GRADE 10 EXAMINATION SYSTEM

An alternative assessment system to the current MYR and MYE examination has been proposed (Britt 1979, Siford 1979). The system, based on one successfully operated in the Nelson and Marlborough Counties in New Zealand during 1975–79 (Nightingale 1979), would relate more closely to the syllabus, testing factual recall, comprehension, application and some analysis and synthesis in a five tier testing programme offered during two testing periods. The system is presented schematically in Table 3.

Table 3

A Five Level Grade 10 Criterion-Reference Testing System

Level of Test	Test Emphasis	Approximate grade equivalent and purpose
1	Factual Recall Comprehension	Grade 6 (Basic knowledge/skills)
2	Factual Recall Comprehension Application	Grade 8 (Emphasis practical skills)
3	Comprehension Application Analysis	Grade 10 (Emphasis on technical training)
4	Comprehension Application Analysis	Grade 10 (Emphasis on further education)
5	Application Analysis Synthesis	Grade 10 (Similar to MYRE testing skills not content)

Note: Papers 1–4 would be marked at the school level. Paper 5 would be marked at national education headquarters.

There would be five levels of achievement. There would be two testing periods, May and October/November. During the first period (May) four tests would be available – one for each of the first four levels. Five tests would be available during the second testing period, one for each of the five levels.

Students may take one, or at most two, of the tests at each testing period. Which test or tests should be taken and when, would be mutually agreed by the teacher and the individual students. As a general rule in the first testing period poor students would take Tests 3 and 4. In the second period, Test 5 may be taken by students who have passed at least Test 3 during the first testing period. The minimum content and skills required and concepts to be understood for each of the first four levels would be carefully specified in terms of syllabus objectives.

Students would be required to score at least 75% to demonstrate mastery at that level before being allowed to sit for the test at the next level.

The advantage of this system would be to motivate teachers and students towards the kind of mathematical learning which Britt (1979: 1) describes as primarily, "not to perpetuate knowledge or just to extend existing knowledge but rather to foster the creation of new knowledge derived from the solutions of new problems that are being recognised now, or will be in future".

A NATIONAL SYSTEM OF CRITERION-REFERENCED TESTS

A recently completed (but as yet unreported)* research study into the possibility of introducing a system of criterion-referenced tests into primary and secondary schools, in a sense, extends the ideas of Britt and Siford to cover assessment in Grades 1 to 10. This viability study was carried out by Gay Townsend of the Education Research Unit, UPNG, at the request of the Department of Education.

In the draft of her report Townsend stated that criterion-referenced measurement has two major advantages for Papua New Guinea:

(a) Syllabus objectives must be stated explicitly; this helps the teacher to see exactly what students should be able to do at the end of a given period of instruction.

(b) The information yielded by such measurement will:

1. provide data for teachers to diagnose student and teaching problems;
2. provide ranks for selection purposes;
3. provide information on teacher weaknesses for use in in-service, etc.;
4. give feedback to curriculum writers on problem areas in the syllabi;
5. provide data on standards in relation to the syllabi;
6. yeild data for comparisons between schools.

The items from which the tests would be constructed would be stored on a computer and drawn upon to provide national examinations as and when required and also tests for school inspectors and curriculum developers. Clearly, a wide ranging and flexible system of assessment, accessed from a computer data base, as suggested in Townsend's draft report, would help to correct many of the faults existing in the present assessment system. However, as can be easily imagined, some considerable obstacles stand in the way of the establishment of a criterion-referenced assessment system in Papua New Guinea.

The Major ones appear to be:

(a) Finance for the co-ordinator of such a project, for a computer specialist to help establish the item bank, for the travel costs of the teacher's college lecturers, and others who would be needed to develop the test items, etc.

* The report has since been published. See Townsend, et al 1980.

(b) Fortunately, in Mathematics the syllabi are already written broadly in behavioural terms but some work would still need to be done to more clearly specify objectives.

(c) Time out from other work would need to be found for those people involved in item writing thus running the risk of diluting the service in the teaching area.

Townsend recommended that a system of bi-annual criterion-referenced tests in English and Mathematics be introduced for Grades 4, 5 and 6 and that unit (usually two or three weeks of work) tests in English and Mathematics be developed for Grades 7–10.

The presentation of the details of this proposal to introduce a system of criterion-referenced tests into the school system is beyond the scope of this paper. However, a full report will be available shortly which will provide the interested reader with the operational description of the system as recommended by Townsend. (That report is now available – Townsend et al 1980).

CONCLUSION

Assessment of mathematics achievement in Papua New Guinea today does little more than facilitate the selection by rank (as opposed to measuring the achievement of objectives set by the curriculum) of students for higher education or training.

Little information on students' actual achievement levels on tests and examinations is returned to curriculum developers, and that which is remains largely untouched for want of time and expertise to analyse and report on it.

Educators and training personnel in post-secondary institutions are seriously concerned about the inability of the entrants to their institutions to cope with the basic mathematical content of the courses offered.

A system of criterion-referenced tests has been proposed which, it would appear, could provide the objectives, the motivation and the information presently lacking in the country's national assessment system.

It would appear that the Department of Education has now to make its decision on the priority status of this proposal, or develop some other means of assessing the results of classroom instruction in relation to prescribed syllabus objectives.

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APPENDIX: SUMMARY OF ALL SCHOOLS/COLLEGES AND ENROLMENTS: BY PROVINCE, TYPE OF SCHOOLS IN 1979

PROVINCE	COMMUNITY SCHOOLS		INTERNATIONAL PRIMARY SCHOOLS		PROVINCIAL HIGH SCHOOLS		INTERNATIONAL HIGH SCHOOLS		NATIONAL HIGH SCHOOLS		TECHNICAL COLLEGES		SKULANKAS		VOCATIONAL		TEACHER EDUCATION	
	No. Schools	Enrol.	No. Schools	Enrol.	No. Schools	Enrol.	No. Schools	Enrol.	No. Schools	Enrol.	No. Colleges	Enrol.	No. Skulankas	Enrol.	No. Centres	Enrol.	No. Col.	Enrolments
Western	75	8592			3	1204									4	192		
Gulf	83	6482			3	777									3	71		
National Capital	27	11229	6	2380	5	2103	1	621			2	1080			6	510	1	427
Central	112	12733	1	16	6	2119			1	432					3	141		
Milne Bay	149	14728			4	1748							1	48	6	332		
Oro	73	8409	1	66	2	988							1	45	4	213		
S/Highlands	122	17985	2	89	6	1753									3	77	1	156
E/Highlands	162	24243	2	258	5	1878			1	380	1	170			3	49		
Simbu	80	13328	1	35	5	1922									1	87		
W/Highlands	101	17570	3	304	6	1770					1	84			3	288	1	220
Enga	66	11618	1	30	4	1244									1	38		
Morobe	169	26009	3	877	7	2579	1	164			1	393	1	47	6	686	1	281
Madang	113	17206	1	206	5	2190					1	170			6	298	1	298
West Sepik	100	10696			4	1194									7	334		
East Sepik	137	20690	1	194	5	2076			1	844					7	288	1	231
Manus	51	3398			2	745									2	73		
New Ireland	97	7436	1	100	5	1839							1	85	3	236		
E/New Britain	112	19843	5	585	8	3351			1	386	2	621			6	300	3	469
W/New Britain	81	11501	1	32	4	1217									3	144		
N/Solomons	124	13796	3	579	5	1933					1	109			4	210		
TOTAL	2014	277301	32	5750	94	34626	2	785	4	1521	9	2607	4	225	79	4299	9	2101

Note:

1. Central – 144 Community schools in 1978. Two of these were combined early in 1979. Another 4 were closed and will not be reopened next year. Low enrolment was the main cause of the closure of these schools.
2. Simbu – 85 schools commenced early in the year. However 5 were later suspended, (but will be reopened next year) because of tribal fighting.
3. W/Highlands – Early in the year there were 104 schools. However 2 were suspended by PEP for an indefinite period due to very poor community support and protection of school facilities. One new school was later closed because of inadequate staff. It will be reopened in 1980.
4. Community school staffing and enrolment figures for the following provinces are based on April (1979) returns. SHP, EHP, Simbu, Enga, Madang, WSP, Manus and North Solomons. The rest are as per July returns.
5. For Goroka Secondary Teachers College which is not in the National Education System but a separate campus of the UPNG, see Table 33.

Source: Planning Services Division, Department of Education, Port Moresby.